Title:

Highly sensitive electrical detection and manipulation of microdroplets on a portable and low-cost microfluidic platform

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Microdroplet-based microfluidic systems are advanced miniaturized platforms for rapid high-throughput analysis, partitioning the sample in nano/picoliter droplets. To realize the parallel operation of droplets, automated droplet detection and manipulation is a pre-requisite. Optical detection systems are widely used, requiring bulky and expensive equipment and fluorescence labelling. Label-free electrical sensing of droplets provides low cost and small footprint alternative, routinely exploiting physical vapour deposition to form coplanar electrodes. The recent re-emergence of Lab-on-PCB (Printed Circuit Board) technology promises lowering the cost of such devices even further, via exploiting standard PCB manufacturing techniques.

In this study, we demonstrate label-free detection and sorting of droplets exploiting PCB electrodes, using off-the-shelf electrical components and reprogrammable electronics (Fig. 1). This system is built as an Arduino board shield, controlling droplet detection and sorting. Sensing is achieved using a capacitive-to-digital converter (AD7746) chip. The microfluidic device is a PDMS based T-junction droplet generator that is attached on top of the electrodes. The system achieved real-time detection of microdroplets (Fig. 2), with a remarkable sensitivity down to 0.5 fF for aqueous droplets in silicone oil. For sorting, dielectrophoretic (DEP) manipulation of the detected microdroplets was incorporated on the same platform. The DEP force was generated by comb-like electrodes (Fig. 3). The high voltage required to generate the electric field was obtained using a power inverter (CXA-M10L-L, V_{rms}= 1200V@31kHz).

Thanks to the integration of all detection and manipulation electronics with the PCB sensing/actuating electrodes, the presented system achieves very high performance at very low cost. The system demonstrated highly sensitive droplet detection and also microdroplet sorting at droplet velocities of 10 mm/s. Additionally, the PDMS microchannels are reversibly placed on the PCB and thus can be replaced in the case of clogging or contamination, assuring the re-usability of the platform.

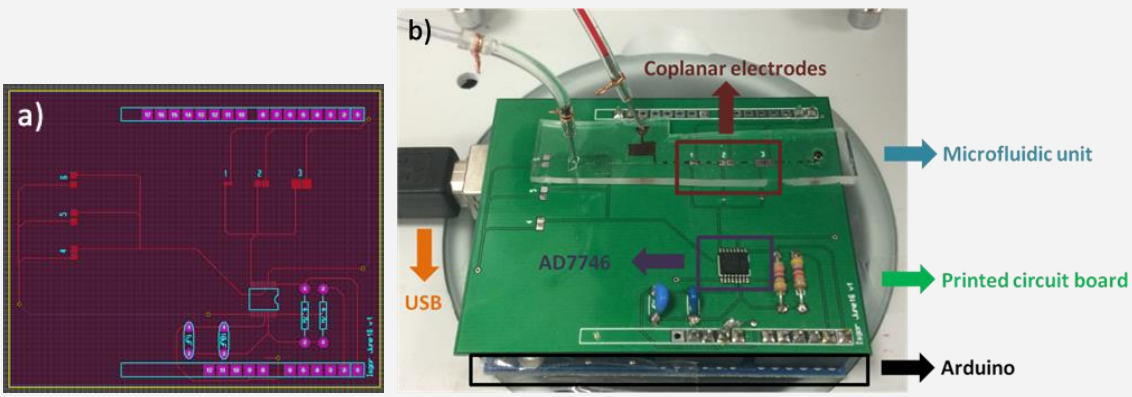

Fig. 1. (a) the PCB layout showing six different electrode designs, (b) photo of the integrated system

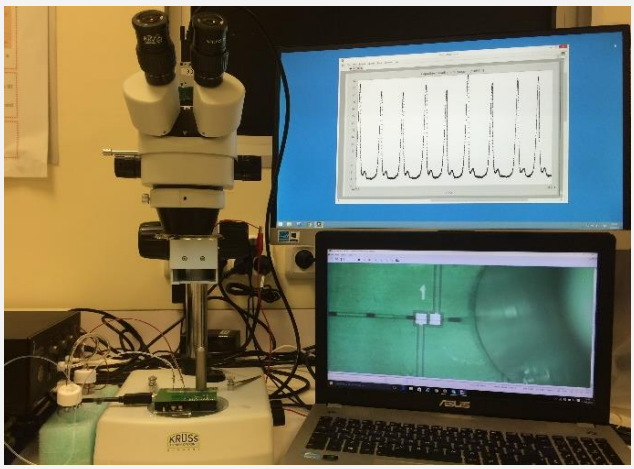

Fig. 2. Photo of the experimental setup used to verify the electrical droplet detection performance

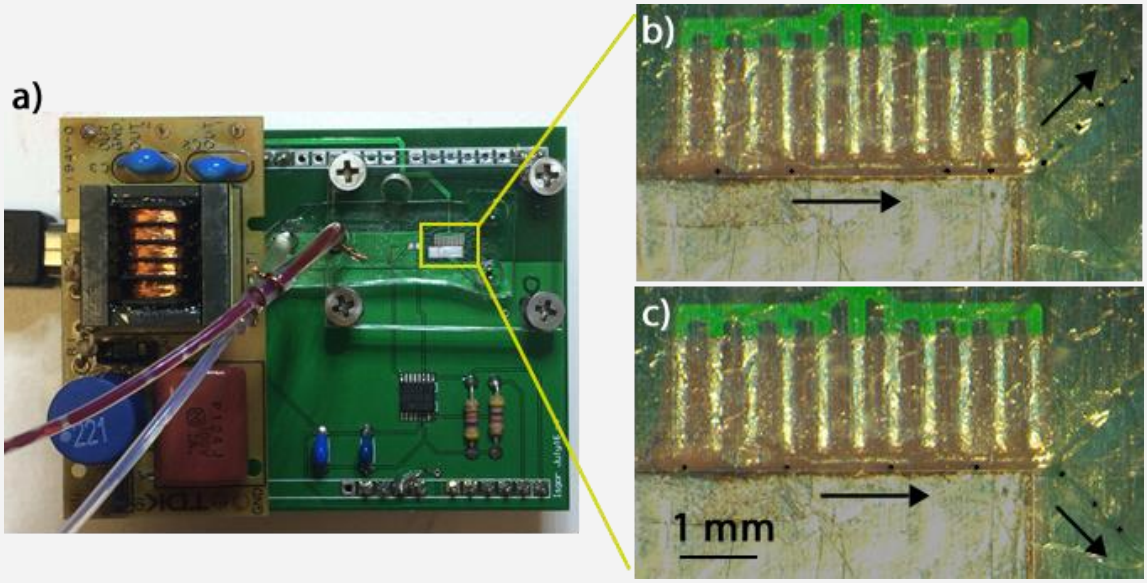

Fig. 3. Photos of the integrated droplet detection and sorting device: (a) the top view of PCB, (b) droplets sorted to the upper channel. Voltage = ON, (c) droplets sorted to the lower channel, Voltage = OFF